



Multi-Scalar Pathways to Smallholder Adaptation



Morey Burnham^a, Zhao Ma^b

^a Idaho State University, Pocatello, Idaho, United States

^b Purdue University, West Lafayette, Indiana, United States

ARTICLE INFO

Article history:

Available online 21 September 2017

Key words:

agricultural decision-making
livelihoods
climate change adaptation
social–ecological change
pathways
China

ABSTRACT

Smallholder farmers in the Loess Plateau Region of China are highly vulnerable to climate change. Effective adaptation governance requires in-depth, situated understanding of how adaptation is embedded in particular environmental, social, political, economic, and institutional contexts. Drawing on 93 qualitative interviews with smallholder households in five counties across three provinces on the Loess Plateau, we use a multi-scalar pathways approach to analyze two particular adaptations (planting maize and adopting drip irrigation). Our results show (1) how historical and ongoing multi-scalar, social–ecological processes interact to shape smallholder adaptation decision-making, leading to synergies, tensions, and contradictions across risk management domains and social institutions; (2) whether an adaptation strategy persists over time is in part determined by the extent to which the strategy allows smallholder households to manage various forms of risk and uncertainty in both the present and future; and (3) how past and ongoing multi-scalar adaptation pathways determine not only smallholder exposure to current stressors but also possible choices for future adaptation. Specifically, we find some smallholder adaptive strategies, such as planting maize, stabilize over time because they enable smallholders to manage market risk, climatic risk, and water pollution challenges, allow them to take advantage of opportunities to diversify their livelihoods through local wage work and labor migration, and, at the same time, fit the local social institutions that guide their agricultural management decisions. We also find some adaptive strategies promoted by non-local actors, such as drip irrigation, are abandoned because they create tensions with the ways smallholders construct their livelihoods to manage various forms of uncertainty and risk, and contradict the local social relations and cultural values embedded in their day-to-day lives. Together, these results provide insight into why particular smallholder adaptation pathways become stabilized and reproduced over time, and the cross-scalar environmental, social, political, economic, and institutional processes that underpin them.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Over the last decade, the concept of adaptation has reemerged in the scholarly literature in the context of climate change, much of it with a focus on examining how smallholder agriculture is affected by and adjusts to climate change. Today, adaptation is broadly used to describe the process of adjusting agriculture and agricultural livelihoods to the impacts predicted to arise from a changing climate (Orlove, 2009). A raft of recent research has examined the adaptation strategies smallholder farmers in the Global South employ to reduce harm caused by and risks associated with climatic and other social–ecological changes (see reviews by Burnham & Ma, 2016 and Harmer & Rahman, 2014). Multiple theoretical lenses have been used to examine smallholder adaptation to climate change, including adaptation governance (e.g., Agrawal, 2010; Huitema et al., 2016; Rodima-Taylor, Olwig, & Chhetri, 2012); adaptive capacity and social capital (e.g., Adger, 2003;

Pelling & High, 2005; Smit & Wandel, 2006); social–cognitive models of adaptation decision-making (e.g., Grothmann & Patt, 2005; Singh, Dorward, & Osbahr, 2016; Spence, Poortinga, & Pidgeon, 2012); risk perception and management (e.g., Field, 2012; Jones & Preston, 2011; Osbahr, Dorward, Stern, & Cooper, 2011; Thomalla, Downing, Spanger-Siegfried, Han, & Rockström, 2006); livelihoods frameworks (e.g., Eakin & Luers, 2006; Orr & Mwale, 2001; Scoones, 2009); and vulnerability (e.g., Adger, 2006; Eakin, 2005; Nelson et al., 2016; Reed et al., 2013; Turner et al., 2003). Much of this previous research is framed with an urgency predicated on the knowledge that significant climate change will happen regardless of mitigation efforts, and that climate change will interact with ongoing social–ecological stressors, both exacerbating them and creating new ones (Adger et al., 2009).

Within the literature on smallholder climate change adaptation, several binary and categorical conceptualizations that describe the function, temporality, origin, and purpose of different adaptation

practices are discussed, including coping versus adaptation, proactive versus reactive, autonomous versus planned, and incremental versus transformative (Singh et al., 2016; Thorn, Thornton, & Helfgott, 2015). For example, the concept of autonomous adaptation denotes changes households or individuals make to address climatic and other stressors, either reactively or as ex-ante measures designed to reduce potential harm, while planned adaptation refers to strategically planned actions by governments, development agencies, or other actors to enable a target population to adapt to climate change or make them less vulnerable to it (IPCC, 2007). Most empirical studies of smallholder adaptation have focused on autonomous adaptation practices undertaken at the household scale, and are typically framed as contributing a baseline knowledge of existing adaptation practices and adaptive capacities within vulnerable communities that can be built on to develop locally appropriate planned adaptations (e.g., Bawakyillenuo, Yaro, & Teye, 2016; Roco, Engler, Bravo-Ureta, & Jara-Rojas, 2014; see also Burnham & Ma, 2016). This literature has argued adaptation interventions that incorporate local knowledge and practices into their design are more likely to be successful and avoid privileging technological interventions ill-fitted to local adaptive capacities, agricultural management practices, social relations, and institutions (Agrawal, 2010; Crane, Roncoli, & Hoogenboom, 2011; Eriksen et al., 2011; Lemos, Boyd, Tompkins, Osbahr, & Liverman, 2007; Naess, 2013).

Recent work has highlighted that the boundaries between these categorical concepts are fuzzy, and that analytical reliance on them can be counter-productive as it may mask the social processes that shape adaptation practices (e.g., Agrawal, 2010; Osbahr, Twyman, Adger, & Thomas, 2008). For example, autonomous adaptations do not occur independently of governmental and development policy (Adger & Vincent, 2005). Instead, autonomous and planned adaptations often occur simultaneously and interact to shape the effectiveness of the other (Milman & Warner, 2016). Further, the types of proactive and reactive adaptations chosen at the household scale and their effectiveness are shaped by social, political, and economic processes occurring at other scales. Likewise, the boundaries between coping and adaptation are murky as repeated exposure to climate variability and change blurs boundaries between the two and coping strategies may morph into adaptations (Agrawal, 2010).

Furthermore, viewing climate change adaptations taken by smallholders as responses to changes in climatic conditions alone may not be helpful for understanding why smallholders make decisions to engage in or change their agricultural and livelihood practices in ways that directly or indirectly, intentionally or unintentionally, help them address climate change-related challenges over time (Burnham & Ma, 2016; Mercer, Perales, & Wainwright, 2012). As Forsyth and Evans (2013) have argued, it is imperative to understand smallholder adaptation to climate change within the context of their livelihood activities and interacting institutional changes if local knowledge and adaptation practice are going to be successfully integrated into adaptation planning at larger scales (also see Eakin, 2005). They contend adaptation must be conceptualized as actions undertaken by smallholders with the intent to maintain their livelihoods in the face of social–ecological change, as opposed to the “control of physical hazards without connection to livelihoods.” In this vein, a growing body of literature has shown that multi-scalar issues such as political economy, power, and social institutions (e.g., property rights) are often more important drivers of smallholder decision-making than are climatic concerns or impacts (Agrawal, 2010; Burnham, Ma, & Zhu, 2015; Eakin, 2000; Hageback et al., 2005; McDowell & Hess, 2012; Mertz, Mbow, Reenberg, & Diouf, 2009; Mertz et al., 2010; Osbahr et al., 2008; Thomas, Twyman, Osbahr, & Hewitson, 2007; Tucker, Eakin, & Castellanos, 2010). While the question of what shapes the types of adaptation smallholders undertake has been

the subject of much research, little attention has been given to the interactions between adaptation practices developed and implemented at different but linked scales within a broader social–ecological context, and the question of how contradictions and synergies between them shape ongoing and future adaptation pathways remains understudied.

In this paper we bring together perspectives from recent literature that has highlighted the importance of investigating how cross-scalar processes shape household adaptation decision-making (e.g., Feola, Lerner, Jain, Montefrio, & Nicholas, 2015; Osbahr et al., 2008) and how past adaptation pathways have emerged by placing them in their historical and social contexts (e.g., Barnett et al., 2014; Fazey et al., 2016; Wise et al., 2014). We present a case study of smallholder household adaptation decision-making to climate variability and change and other social–ecological changes in the Loess Plateau Region of China, with a focus on two specific smallholder household adaptation practices: the planting of maize and the adoption of drip irrigation. We ask the following three research questions: (1) Why do smallholder households choose to undertake these adaptation practices or not? (2) What are the tensions, contradictions, and synergies between the adaptation practices employed by smallholder households and the adaptation interventions introduced by non-local actors at various scales? And (3) how does smallholder household adaptation interact with broader environmental, social, political, economic, and institutional processes to shape ongoing and future pathways of change and response? We use interview data collected in three provinces to analyze and demonstrate how smallholder household adaptation and livelihood practices create pathways conducive to certain adaptation interventions but unconducive to others. Specifically, we find some household adaptation strategies, such as planting maize, stabilize over time for two primary reasons. First, it enables smallholders to not only manage the largest number of interacting risks in the present (compared to other adaptation alternatives), including market, pollution, and climatic risks, but also take advantage of opportunities to diversify their livelihoods through local wage work and labor migration, thus maintaining livelihood flexibility to address future risk and uncertainty. Second, it fits the local social institutions that guide smallholder agricultural management decisions. In contrast, we find some smallholder adaptation strategies developed and promoted by state actors, such as drip irrigation, contradict with the ways smallholders construct their livelihoods to manage present and future risk, and create tensions with the social institutions embedded in their livelihood practices, leading to their failure and abandonment. Overall, our case study enables us to understand the reasons behind the stabilization and reproduction of smallholder household adaptations, particularly how they function as the risk management strategies and the social, political, economic, and institutional processes that underpin them. This understanding leads to insight into how smallholders make adaptation choices that reflect their attempts to manage risk and uncertainty in the present while maintaining their options to take actions to mitigate risk in uncertain environmental and institutional landscapes in the future.¹

2. Analytical framework

To address our three research questions, we combine two inter-related lenses to examine smallholder adaptation decision-making. First, we examine how *multi-scalar processes* converge to mediate how climatic and other forms of social–ecological risks are experienced locally and acted upon through adaptive practice. Second,

¹ We thank an anonymous reviewer for making this point and helping us to clarify our argument.

we investigate how smallholder adaptation actions and inactions are part of *pathways of change and response* in which they seek to manage present and future risk by considering (explicitly or implicitly) the tradeoffs that adopting various adaptive practices would incur for their ability to manage the changing environmental and institutional landscapes over time.

As noted in the introduction, recent work on climate change adaptation has shown that adaptive livelihood practices undertaken by smallholder households are the outcomes of both individual agency and structural processes (Adger, Arnell, & Tompkins, 2005; Eakin, 2000; Eakin, Winkels, & Sendzimir, 2009). They are co-determined by engagements of local-level actors with various cross-scalar institutions, policies, economies, and actors (Adger et al., 2005; Birkenholtz, 2012; Eakin, 2000; Feola et al., 2015; Leichenko & O'Brien, 2008; Osbahr et al., 2008; Wise et al., 2014). Further, researchers have argued that adaptation is not necessarily a particular behavior, but rather the “suite of beliefs and practices related to risk and its management” that occur within locally specific relationships between the environment, economy, and society and their interrelated uncertainties (Carr, 2008: 693). Likewise, particular forms of adaptive practice have been shown to be entangled with historical legacies and social contexts (Fazey et al., 2016), institutional arrangements (Agrawal & Perrin, 2009; Wang, Brown, & Agrawal, 2013), political economy (Eakin, 2000), socio-cognitive factors (Burnham & Ma, 2017; Frank, Eakin, & López-Carr, 2011; Grothmann & Patt, 2005; Jones & Boyd, 2011; Singh et al., 2016), and socio-cultural values and norms (Curry et al., 2015; Wolf, Alice, & Bell, 2013). Thus, scholars have highlighted the importance of investigating how cross-scalar interactions and multiple stressors shape household adaptation decision-making as this can provide insight into the processes affecting on-the-ground experiences of risk and the factors facilitating or delimiting a household's ability to adapt to change (Burnham & Ma, 2016; Feola et al., 2015; Leichenko & Silva, 2014; Osbahr et al., 2008; Taylor, 2015).

More broadly, several scholars have called for adaptation research to focus more on how and why particular forms of household adaptation stabilize and persist over time, rather than treating adaptation decisions to change agricultural or livelihood practices as discrete events (Carr, 2008; Feola et al., 2015; Scoones, 2009; Wise et al., 2014). For example, Fazey et al. (2016) have applied a pathways lens to investigate how adaptation trajectories emerge and become embedded within particular environmental, economic, political, and social contexts across scales. This approach views adaptation not as discrete actions undertaken in response to specific or isolated instances of change, but rather as “entangled in on-going processes of social-ecological change and their associated politics” (Manuel-Navarrete & Pelling, 2015: 559). In other words, adaptation pathways can be conceptualized as “a series of adaptive learning decision cycles” in the face of various forms of “uncertainty and inter-temporal complexity,” where some pathways lead to maladaptation over time while others preserve adaptive alternatives for the future (Haasnoot, Kwakkel, Walker, & ter Maat, 2013; Wise et al., 2014: 326). Conceptualizing adaptation in this way allows researchers to identify “patterns that explain how and why change occurs and how this results in particular outcomes,” as well as how and why certain changes do not occur or expected outcomes are not produced (Fazey et al., 2016: 28). Likewise, this conceptualization enables understanding of how legacies of past adaptation, including the informal and formal social institutions and socio-cultural values and preferences that underlie them, become embedded and reinforced in smallholder farming systems and shape future adaptation trajectories (Barnett et al., 2014; Leach, Scoones, & Stirling, 2010). Further, conceptualizing adaptation as pathways provides an analytical approach for exploring and sequencing various changes in a social-ecological system in

order to provide insights into the ways particular adaptation outcomes are produced, re-adapted, or abandoned over time (Haasnoot et al., 2013). Thus, a pathways lens enables us to examine “the temporal and/or spatial co-evolution of different driving forces” of adaptation (Nielsen & Reenberg, 2010: 465) and ground adaptation in “social, subjective, historical and political processes” that are themselves dynamic and unfolding (Adger et al., 2009; Manuel-Navarrete & Pelling, 2015: 561).

In this paper, we draw upon previous literature on both *multi-scalar processes* and *adaptation pathways* to highlight how smallholder household adaptive practices are embedded in and emerge from the multi-scalar environmental, social, political, economic, and institutional contexts in which smallholders live and work in ways that allow them to manage the temporal complexity of risk in a changing social-ecological system. By understanding adaptation decision-making through this multi-scalar pathways lens, dichotomies such as autonomous versus planned or reactive versus proactive adaptation are eschewed in favor of understanding smallholder household adaptive decision-making as a dynamic process influenced by “diverse and interdependent pathways of change and/or responses” operating concurrently at different social, temporal, and spatial scales (Fazey et al., 2016: 37). Further, this multi-scalar pathways lens allows us to identify the contradictions, tensions, and synergies across current and future risk management domains and social institutions that arise when new adaptation interventions, such as the promotion of drip irrigation, interact with ongoing adaptation pathways that are shaped by previous policy changes and social transitions.

3. Study site

This study was conducted in five counties across three provinces in the Loess Plateau Region of China: Mizhi and Yangling in Shaanxi, Hongsipu (a county-level municipality) in Ningxia, and Ganzhou and Gaotai in Gansu (Figure 1; Table 1).

The Loess Plateau Region of China is located at about 37 degrees north latitude in the middle and upper reaches of the Yellow River, spanning an area of approximately 647,250 square kilometers and covering parts of five provinces. The climate is a typical continental monsoonal climate, and the advance of the East Asian Monsoon each year causes the region to have distinctive wet and dry seasons (Ding & Chan, 2005). The climate ranges from arid/semi-arid to sub-humid, and averages about 140 mm of rainfall in the northwest most section to 800 mm in the southeast. Approximately 70% of annual precipitation falls between June and September in the form of heavy storms, leaving many crops vulnerable to drought in the early growing season (Li, Zheng, & Liu, 2012). Over the last 40 years, the region has experienced steadily rising temperatures, and has seen erratic, but slightly decreasing rainfall (Li et al., 2012). Drought frequency and intensity have also increased across much of the region (Zhang, Wu, Zhao, & Gao, 2013). Future climate change is predicted to cause increases in average annual temperature and drought frequency, changes in the timing of rainfall, decreased water availability, and increased soil erosion (Wu, Verburg, & Tang, 2013). Additionally, intense precipitation events are likely to increase (Li, Zheng, Liu, & Flanagan, 2010), while decreased runoff from the Yellow River is expected to lead to water shortages that will be made worse by a growing population (Li et al., 2010; Piao et al., 2010). These changes in climatic and social conditions will continue to threaten the already highly vulnerable agriculture sector in the Loess Plateau Region (Wu et al., 2013).

In addition to a changing climate, wide-ranging reforms to the agricultural sector and rural China more broadly have transformed landscapes, agricultural practices, and livelihoods on the Loess Plateau over the past 40 years. In the early 1980s, decollectivization of

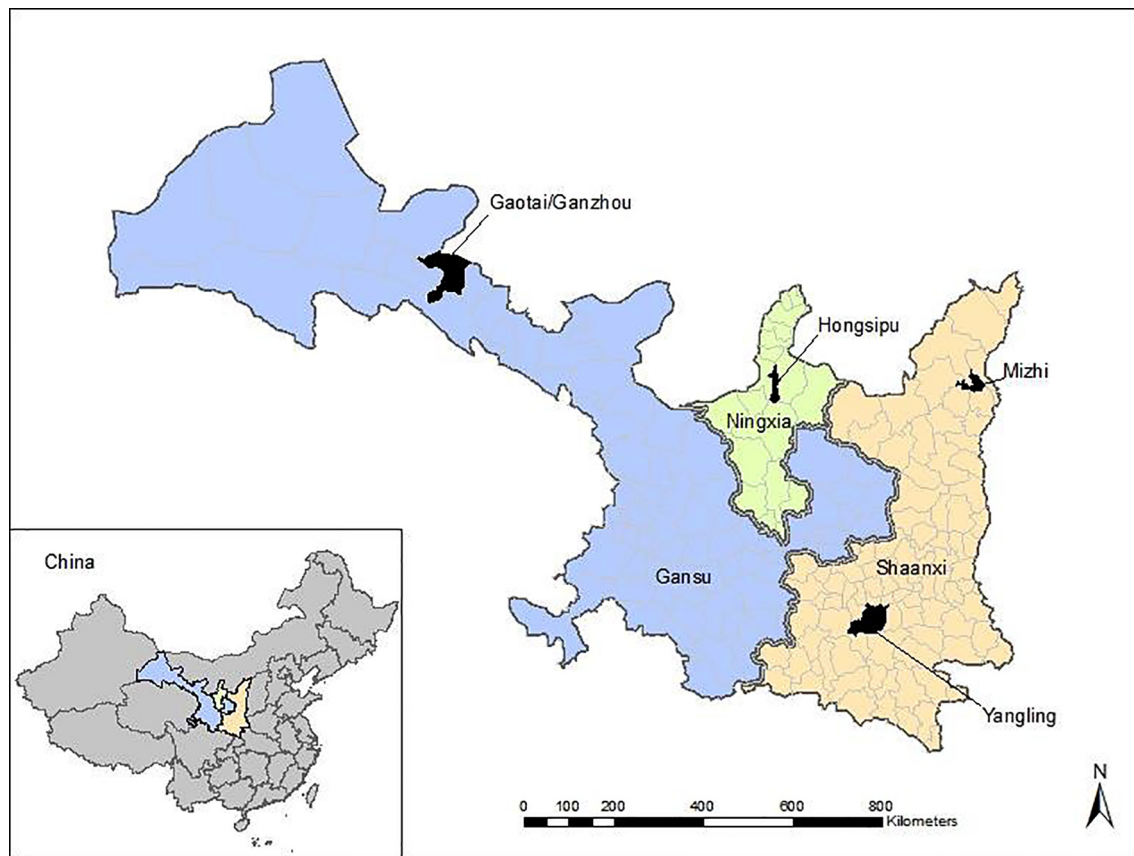


Figure 1. Map of study area.

Table 1
Study sites, annual rainfall, and irrigation method used at the village level

Province	County	Township	# of villages interviewed	# of interviews	Average annual rainfall (mm)	Irrigation method used at the village level
Ningxia ^a	Hongsipu (county-level district)	Hongsipu; Nanchuan	2	16	~260	Flood irrigation
Shaanxi	Mizhi	Shilipu; Yinzhou	4	29	~450	Flood irrigation
	Yangling (county-level district)	Dazhai; Yangcun	3	21	~635	Flood irrigation
Gansu	Gaotai	Luotuocheng	2	11	~103	Flood irrigation (Note: Drip irrigation was adopted in one village but abandoned later.)
	Ganzhou (county-level district)	Dangzhai	2	16	~115	Drip irrigation in one village, flood irrigation in the other

^a Ningxia is technically an autonomous region, not a province.

agricultural production through China's "Household Contract Responsibility System" provided individual households with usufruct rights to plots of land for 30 years (Tilt, 2008). Starting in the 1980s, the state has made changes to the *hukou*² system, facilitating "temporary" migration of farmers to urban areas for work (Fan, 2003). Heavy state investment in irrigation projects such as canals, reservoirs, dams, and wells starting in 1949 has led to an increase in irrigated area from 44.9 million ha in 1980 to 62.9 million ha in 2006 (FAO, 2011; Zhu, Li, Li, Pan, & Shi, 2013). In 2006, the Chinese government abolished the agricultural tax on grain production, resulting in higher levels of disposable income for many farm households (Veeck & Shui, 2011). This abolishment of agricultural tax was

part of the broader effort to formulate a "New Socialist Countryside," which in part sought to improve rural livelihoods and infrastructure, including irrigation systems and roads (Day, 2013; Veeck & Shui, 2011).

4. Methods

The data analyzed in this paper are qualitative and were collected as part of a large-scale, mixed-methods study focused on how smallholders in the Loess Plateau Region of China experience, perceive and adapt to climate and other social-ecological changes. The study was conducted in two steps. In 2011 (year 1), we collected qualitative interviews data through 56 unstructured and 37 semi-structured interviews with smallholder farmers in 13 administrative villages from five counties across three provinces in the Loess Plateau Region (Hongsipu in Ningxia, Mizhi and Yan-

² The *hukou* system identifies a person as a resident of a particular area, as well as if they are a rural or urban resident. The system regulates population distribution and rural-to-urban migration.

gling in Shaanxi, and Ganzhou and Gaotai in Gansu). To include a diversity of socioeconomic, geographical, and agroecological conditions as part of our study, we included villages and households that practice either rainfed or irrigated agriculture, and are located at different distances from the local population center. Two approaches were used to identify and recruit initial interviewees. First, we contacted agricultural researchers from a regional university to recommend potential interviewees from our selected villages without specifying gender, age, and types of crops grown. We then approached these individuals and invited them to participate in an interview. Second, we directly approached villagers randomly as we walked around our selected villages and invited them to participate in an interview. After securing the initial group of interviewees, we used a snowball sampling strategy to recruit more smallholder households for which agriculture was an important component of their livelihood strategies. The final set of 93 interviewees had various demographic, socioeconomic, and farm characteristics (Table 2). All our interviewees' households were engaged in some form of agricultural production.

Most interviews were conducted with the smallholders while they were working on their farms, often with the researchers assisting them with the completion of everyday tasks, such as weeding, harvesting, and irrigating. The semi-structured interviews were conducted using an interview protocol constructed to elicit an understanding of general village and farming life; smallholder perceptions of climate change and associated risk; their perceptions of and experience with various social–ecological changes in their village, county, province, and beyond; their major sources of livelihood challenges and risks; the changes they have made to farming practices and livelihoods over the past 30 years and why; and their social and professional networks. This interview protocol was designed to enable study participants to explain their responses in detail, allowing for a fine-grained understanding of what climate and other social–ecological changes mean to them, how the changes are experienced in their daily agricultural practices in contingent ways, and how they make decisions to respond to different changes (Yeh, Nyima, Hopping, & Klein, 2014). The semi-structured interviews lasted from one hour to three hours. Unstructured interviews were conducted when smallholders agreed to be interviewed but did not have enough time to complete a full-length interview. The unstructured interviews lasted 30 min on average. The questions asked during unstructured interviews were based on the semi-structured interview protocol, but allowed more leeway for interviewees to dictate the flow of conversation. Specifically, we allowed interviewees to skip questions they felt were less important to them, and spend more time discussing what they felt were more important for us to understand how their livelihoods had been impacted by climate and other social–ecological changes and how and why they had made changes to their livelihood practices.

In 2012 (year 2), we implemented a quantitative survey of 483 smallholder households across our study region, including in the villages where we conducted interviews in the first year. In the survey, we asked smallholder farmers what changes they have made to their farming practices and livelihoods in the past 30 years. We used a list of changes and practices that was developed based on a comprehensive literature review and through qualitative interviews with smallholders in the previous year. Descriptive statistics (Table 3) show that the most common change reported by smallholder survey respondents was the planting of maize and the least common change was the adoption of drip irrigation. The disparity in adoption rates documented in the survey results motivated us to return to the qualitative data collected in the previous year to analyze it to address our three aforementioned research questions within the context of these two smallholder household adaptation practices. We decided to focus our qualita-

tive data analysis on planting maize and adopting drip irrigation, two of the many adaptive practices discussed by our interviewees. We recognized that limiting our analysis to two specific practices may elide a comprehensive view of the suite of adaptive practices smallholders can adopt and their associated implications for creating or reinforcing pathways of change and response. However, choosing to focus on these two practices enabled us to gain a deeper understanding of the contrast in adoption rates—why maize was so widely planted and why drip irrigation was rarely used—by teasing out in detail the multi-scalar pathways that shaped these two adaptive practice and led to their persistence or abandonment on the ground. As such, findings from analyzing these two practices offer broader insights into smallholder household adaptation decision-making in general.

To address our three research questions, each interview was transcribed verbatim in Chinese and translated into English before being analyzed. Two researchers manually coded each transcript independently to ensure inter-coder reliability (Campbell, Quincy, Osserman, & Pedersen, 2013). Each transcript was analyzed using a three-step process Neuman (2011). In the first step, each transcript was coded to identify major themes and insights relevant to smallholder adaptation to climate change and other social–ecological changes. These initial codes were compared between the two coders to identify agreements and disagreements, then revised and combined into one set of codes (i.e., the codebook). A second round of coding was conducted using the codebook to organize key ideas and identify sub-themes within the initial set of major themes with a focus on characterizing smallholder experiences of climate change and other risks, as well as how and why they adapt to them. The final step was used to selectively identify quotes that highlight the themes and sub-themes drawn from the first two steps to provide contextual richness to the findings.

5. Results and discussion

We present our results, focusing primarily on major findings from our interviews but also relying on supplemental, secondary, publicly available data to fill in contextual details about the environmental, social, political, economic, and institutional contexts in which our smallholder interviewees live and work. Specifically, we focus on the two smallholder household adaptation practices previously identified through a household survey (planting maize and adoption of drip irrigation), and explain why these practices have stabilized or discontinued over time and how such adaptation decisions interact with multiple stressors and processes at multiple scales, shaping ongoing pathways of change and response (Table 4).

(a). Situating maize planting in the multi-scalar contexts of smallholder agriculture

In our study region, smallholders primarily grow maize for market purposes. Maize has been planted in China for more than 300 years (Li Jun, personal communication, January 2014). In the Loess Plateau Region, maize's growth cycle coincides with the regional precipitation pattern, in which a majority of the rain falls in July, August, and September. Maize can also deal with low availability of soil moisture during the early growing season, which is the primary limiting factor for crop production in the region (Huang, Chen, & Li, 2011). Thus, smallholder households frequently plant maize as an adaptive strategy as they have sought to mitigate drought risk and other climatic stressors over time.

Maize's continuing popularity as a cropping choice in the Loess Plateau Region, particularly in the more arid northern half, can also

Table 2
Demographic, socioeconomic, and farm characteristics of interviewed smallholder farmers^a

County	Average age (years)	Gender (% of female)	Average education (years)	Average annual household income (Yuan ^b)	Average % of income from agriculture (%)	% of households employing market-oriented strategy (%)	% of households mixed subsistence/market-oriented strategy (%)	% of households engaged in off-farm labor (%)	Most common off-farm jobs	Average total farmland area (ha)	Average number of plots farmed	Primary crops
Hongsipu	45	47	8	40,189	38	45	55	81	Construction; commercial farm	12	3	Maize; goji
Mizhi	50	41	7	26,525	53	36 ^c	40 ^c	59	Construction; truck driver; coal mines	5	5	Maize; watermelon; vegetables
Yangling	55	57	7	12,485	40	15	85	57	Construction; factory worker	5	5	Maize; tomatoes; kiwi; wheat
Gaotai	54	57	5	31,938	61	47	53	63	Construction; commercial farm	12	4	Maize; vegetables
Ganzhou	52	44	5	28,645	63	32	68	63	Construction; commercial farm	15	3	Maize; vegetables

^a Data were derived as averages from a subset of the total sample as not all interviewed smallholders provided this information.^b 1 Chinese yuan = 0.16 U.S. dollar.^c The remaining 24% of interviewed smallholders employed a subsistence-oriented strategy.

be linked to efforts by the Chinese government and subsequent research initiatives designed to increase food security and reduce poverty in the region, starting around the early 1980s (Li Jun, personal communication, January 2014). This effort led to an increased availability of drought-tolerant crop varieties, distribution of fertilizer, promotion of technologies designed to manage soil moisture, and building of communal irrigation systems (Meng, Hu, Shi, & Zhang, 2006). Since the late 2000s, climate change has become a major concern of the Chinese government (State Council Information Office of China, 2008), particularly in the Loess Plateau region where rising temperatures, changes in the timing of rainfall, and increasing drought frequency and intensity have been observed and predicted (Li et al., 2010, 2012; Wu et al., 2013; Zhang et al., 2013). As such, government agencies at various levels have increased their research investments on drought-tolerant maize as a climate-smart cropping choice (Fraser et al., 2008; Huang, Pray, & Rozelle, 2002; Yang et al., 2007). Together, these conditions favored the continuation of maize production, and led to the common view that maize is a better crop choice than millet or wheat, both of which were widely planted in the region previously, to simultaneously address the social and climatic challenges present on the Loess Plateau. In particular, as part of this food security and poverty reduction campaign, plastic mulching was widely introduced in the region via various government initiatives. Plastic mulching enables residual soil moisture to be captured and prevents evaporation and attendant soil desiccation, and allowed maize to withstand early season water shortages and facilitated its spread (maize is generally planted in April when there is typically little to no rain) (Li Jun, personal communication, January 2014). This further contributed to the stabilization of maize production as an adaptive strategy over time.

The overall effort to increase food security and reduce poverty also coincided with changes in household food consumption choices, rising per capita income, and urbanization that accompanied the wide-ranging social reforms of the 1980s, which gave agricultural households more control over their land and profits, while also creating opportunities for rural households to earn off farm incomes. Although these changes led to a sharp decrease in the amount of maize consumed as food, they also led to a sharp increase in the use of maize as a feed crop for commercial hog and poultry operations (Huang & Rozelle, 2008), which contributed to a stable if not increasing market for maize.

(b). Smallholder adoption and stabilization of maize planting

Beyond the climatic, political, economic, and institutional processes that have contributed to the stabilization of maize production among smallholder farmers, we describe the following four factors reported by our interviewees as key to understanding why smallholder farmers plant maize planting (Table 4). Specifically, these factors help explain how planting maize has enabled smallholder households to adequately manage the risks and opportunities that emerge from their local social-ecological context while maintaining flexibility to address future risk and uncertainty, and how this has led to such adaptation to be reproduced as a central component of smallholder livelihood strategies. We also describe the ways these factors interact with the broader climatic, political, economic, and institutional processes as previously described (Table 4), as well as how maize fits with and reinforces the social institutions that shape smallholder agricultural decision-making.

(i). Time and labor availability

Despite maize's ability to withstand early season rainfall shortages and reasonable drought tolerance when planted in combination with plastic mulching, in our interviews the most frequently

Table 3

Changes smallholder farmers made to their farming practices and livelihoods in the past 30 years, reported through a household survey

Reported changes	Yangling (n = 160) (%)	Mizhi (n = 161) (%)	Hongsibu (n = 161) (%)	Total (n = 482) (%)
Planting maize	67	93	88	83
Working off-farm	86	54	61	67
Raising livestock	59	63	71	65
Planting drought-tolerant crops	66	59	63	62
Retaining field stubble	60	28	71	53
Doing local wage work	61	31	54	49
Using quick-maturing seeds	68	24	48	46
Increasing cash crops	66	20	32	39
Engaging in labor migration	51	35	29	38
Using plastic mulching	47	47	17	37
Using intercropping	41	9	37	29
Planting seeds earlier	40	14	31	28
Using greenhouse	13	1	7	7
Adopting drip irrigation	10	1	1	4

Table 4

Multi-scalar processes shaping smallholder household decisions to plant maize or adopt drip irrigation and specific reasons reported by smallholder households regarding adoption and non-adoption

Multi-scalar processes shaping smallholder household decisions to...		Reasons reported by smallholder households for...	
Plant maize	Adopt drip irrigation	Planting maize	Not adopting or abandoning drip irrigation
Changing consumption patterns driven by urbanization	Public-private investment on developing water infrastructure and irrigation schemes	Polluted irrigation water	Intrahousehold cooperation required
Technology development (e.g., plastic mulching and irrigation)	State investment in drip irrigation research	Low labor input required	High labor input required
Improved seed technology to address drought and increase yield	State policies to address climate change and aridity	Changing weather and climate	Low labor availability within households
State policy to increase food security and reduce poverty	Decollectivization of agricultural production and the resulting changes in social norms and relations in rural communities	Stable price and government subsidies/low market risk	Increased market risk
Social reform and migration policy	Social reform and migration policy	Land scarcity	Land scarcity

reported reason for planting maize was that it required less labor than other possible choices, such as vegetables or watermelons. Because of its low labor requirements, growing maize enables households to make an income from agriculture while freeing up time for doing local wage labor or by allowing one or more members of a household to pursue temporary or permanent labor migration. While the types of labor opportunities for off-farm work differed across our study counties, in general our interviewees explained that many of their farm management decisions were made to ensure that they had time to perform wage work, as one farmer from Gansu explained:

"Because it takes so little time you can go out and earn money, usually 60–70 Yuan (~\$9–11) per day."

The importance of off-farm work is apparent in our interview data, with over two thirds of our interviewed households having at least one member over the age of 18 engaged in some form of

off-farm work, accounting for about one third of their household incomes.³ These household members held diverse off-farm jobs, including driver, coalmine employee, restaurant worker, construction laborer, and teacher.

Another common refrain echoed by interviewees was off-farm work is preferred to agricultural work for making a living because profits are higher, the labor is easier, and it provides a means to diversify a household away from dependence on agriculture as the only source of income, which is subject to many market and climatic risks. For example, one maize grower made clear that he worked off-farm because it was more lucrative than agriculture, and his family planted maize because it required less labor than other potential crop choices, thus freeing up time for off-farm work:

"Maize can usually earn 1500 [yuan] per mu; watermelon 7000–8000 [yuan] per mu, but planting watermelons is a lot of work. My family does not have enough people [at home] to do the labor [so we] choose to plant maize as it takes less work, even though it earns less money than other crops."

Many maize growers explained that once they planted their maize, they gave it little to no attention other than occasionally weeding or irrigating their plots. For example, one interviewee who worked construction jobs locally stated: *"I just plant my crops and leave it to the gods to determine what happens."* Contrast this with the statement of another maize grower who explained his crop choice, saying:

"I don't plant watermelon because they take a lot of work and you have to look after them very carefully. If it rains too much you have to try to get the water off the plots...and they [watermelons] are hard because you have to prevent pests from eating the leaves."

Further, in our study, it was frequently men who migrated to perform wage labor and women who stayed behind in the village and maintained their households by taking care of young children and elderly parents, leaving them little time for labor-intensive agricultural production. For these women, maize offered an opportunity to still engage in agricultural production and contribute money to the household while also leaving time to perform their other household activities. As one interviewee explained,

"[We plant corn because] my wife does not have enough energy [or time] to plant vegetables and take care of them [because of her other household responsibilities]."

³ Note that we collected data on remittances from migration and wages from off-farm work, but households were often reticent to discuss these topics and the numbers reported here are likely low.

Household labor availability for agricultural work is shaped by naturally occurring household demographic changes over time, but is also determined by cross-scalar policy and social transitions that have changed household livelihood opportunities and decision-making in China (Yeh et al., 2014). Beginning in the 1980s, the Chinese State made changes to the *hukou* system, facilitating “temporary” migration of peasants to urban areas for work (Fan, 2003). Across the country, migration and concurrent socioeconomic changes have led to an estimated 230 million peasant workers migrating for work (Fan, 2003; Ye, Wang, Wu, He, & Liu, 2013). At the same time, local economic development has led to an increase in the number of construction and service jobs available near many of the villages where we conducted our study. Because planting maize requires little labor it enables smallholders to have the flexibility and mobility needed to access a second adaptive strategy in the form of off-farm work, made available to them through policy change and economic development, thus diversifying their livelihoods and reducing the risk that uncertain agricultural production poses to household stability.

(ii). Price stability and high cost of agricultural inputs

The second most frequently cited reason for choosing to plant maize was that the price smallholders received for their crop from buyers is relatively stable, and, while low compared to alternative cropping choices, it is still high enough to make a profit. As noted above, most interviewees preferred wage work in part because it provided a stable and known income source, in contrast to the risk posed to household livelihoods from highly variable crop prices. In their view, this risk was compounded by the challenge posed by low or unfair prices offered from the buyers who came to their villages to collect crops. Many interviewees explained they can nearly always sell their maize for at least one yuan per kilogram, and the market place only fluctuates on the order of 0.1 or 0.2 yuan per kilogram if it does at all:

“We plant corn because the yields are high and the price is stable and high, 1 yuan per kg. We can get about 1,000 kg per mu.”

On the other hand, vegetable farmers frequently complained market prices for their crops were unpredictable and highly variable, putting them at risk of not recovering the capital cost that went into planting their crop. As one vegetable farmer contemplating switching to maize or another crop explained:

“I will sell my youcai (Brassica rappa chinensis) tomorrow morning at 4:00 am in Mizhi. The price right now is more than 2 yuan per jin (1 jin = 0.5 kilo), but last week or so it was only 5 jiao (1 jiao = 0.1 yuan).”

Connected to the risk smallholders perceived in unpredictable markets and highly variable prices, was the often-cited challenge that the cost of inputs, including seeds, fertilizer, and pesticides, was high and often times not recoverable when crop prices are low. Our interviews revealed smallholders frequently chose to plant maize because the overall cost of inputs for maize is lower than for vegetables or other potentially high-value crops.

“Maize is easy to grow and the cost of the inputs is low, so you can make a lot of money from it. There isn’t much risk when you plant maize.”

This, together with the fact that in many of our study villages the local government provides maize growers with a fertilizer subsidy of 10–20 yuan, led smallholders to see planting maize as a strategy to manage the risks posed by high cost of agricultural inputs. In several villages, the local government also offered crop insurance for maize, further reducing risks associated with poor harvests. As one interviewee explained:

“I choose maize because...the government offers insurance for it if you have a bad harvest. Since it takes so little time you can go out and earn money, usually 60–70 yuan per day.”

Relatedly, many of our interviewees also mentioned land scarcity as a determinant of their choice to plant maize. As shown in Table 2, the amount of farmland each household had access to is small, and the situation is exacerbated as the total amount of land was divided over several non-contiguous plots. Because of this, our interviewees felt they had too little land to justify investments in crops or technologies that would incur high input costs, as they feared they would not achieve the economies of scale needed to recoup their costs and make a profit.

(iii). Climate and weather

In addition to labor availability and economic risk, many interviewees reported they chose to plant maize because of its drought tolerance and ability to produce high yields despite dry conditions. Nearly all of our interviewees reported that the climate was changing, and in particular they stated that it had become hotter and dryer than it was in the past and that the intensity of rainfall events, particularly late in the growing season, had increased. As one smallholder explained:

“The climate is hotter and dryer than it was before. When I was a child the river south of the road used to be very high most of the time and there were lots of fish. We used to swim in it and catch the fish. I could play with my shirt off and not get burnt. Now that the rainfall is so little and the sun is so hot in the summer there is not much water in the river.”

Many interviewees went on to explain that these changes in the climate had reduced water availability for agriculture. In Mizhi, the fact that the Wuding River had not flooded since 1999 was often cited as evidence of changing weather and climate. Most of these interviewees were aware and concerned about the negative impacts of these changes on crops and their agricultural livelihoods in general. A common refrain was echoed by one interviewee who stated:

“The changing climate influences my ability to farm. Yields are lower than before and the quality of the crops [at harvest] is decreasing.”

Within this context, interviewees explained they grew maize because it was able to tolerate hot temperatures and increased aridity while still producing high enough yields to make a profit. Indeed, one smallholder went so far as to argue, “there is no new crop which could replace maize,” given the climatic trends on the Loess Plateau. Likewise, many interviewees saw maize as a better choice than other higher value vegetable or fruit crops because it is less vulnerable to heavy rainfall in late growing season. This, coupled with its low input costs, meant planting maize is an investment that is less likely to lose money. Thus, planting maize enables smallholders to accommodate the weather patterns and climatic changes that in part shape their agricultural livelihoods on the Loess Plateau.

(iv). Water pollution

Our interviewees also identified water pollution as a factor that contributed to their households’ decision to plant maize and to the stabilization of this crop choice over time, particularly in three of our study villages in Mizhi. When questioned about why they chose to plant maize, interviewees responded that the irrigation water from the Wuding River they had access to is too polluted to grow anything else. These villagers had grown vegetables and other high-value crops in the past, but largely stopped once an upstream chemical factory that produces PVC using calcium car-

bide started to operate. They attributed the frequent failure of their vegetables and other high-value crops to the polluted irrigation water drawn from the factory, as illustrated by the following quote:

“The vegetables are very weak and if you use the polluted irrigation water all the time they might die... corn is better able to resist the polluted water and has an easier time surviving.”

Another woman who grew sweet potatoes prior to the establishment of the factory explained:

“[About] ten years ago the Jintai factory was built near our fields. Pollution began to get into the irrigation water and drinking water and it hurts our crops. The crops grow worse now than when the factory was not there. The vegetables are very weak and if you use the polluted irrigation water all the time, they might die. We really can't irrigate the watermelons and vegetables with the polluted water because they will likely die. The only thing we can do to solve this is to rely on rainwater for irrigation. If it rains then production is good, but if it doesn't rain then our income is low. On the other hand, maize is able to better resist the polluted water and has an easier time surviving, so we plant maize as it survives better in the irrigation water.”

For some, this water quality challenge exacerbated other challenges they face because it forced them to abandon their crop rotation, reducing the soil fertility in their plots and, they claimed, reduced yields:

“We know planting the same thing over and over reduces production, but because of the pollution in the water we have no choice. The water is really poisonous and only maize can give us a good income, so we plant maize. We can't change this unless the water becomes clean again.”

The water quality challenge faced by our interviewees is the result of cross-scalar economic development processes that mediate both how risk is experienced and acted upon in Mizhi. The polluted water affecting these villages became a problem in 2003 when the Shaanxi Jintai Chlor-Akali Chemical Company, LTD established a factory in Mizhi after project approval was granted by the Shaanxi Province Development and Reformation Commission. The factory's establishment was part of an effort by the Chinese central government to catalyze economic development and industrialization in western China through infrastructure development, private and foreign investment, education, and ecological protection as part of its ‘Open up the West’ (*Xibu da kaifa*) campaign (Yeh, 2005). In Shaanxi, the factory's establishment was also part of a regional effort led by the Shaanxi Provincial Committee to establish the area surrounding Yulin city as an industrial base for chemicals and other forms of heavy industry that could facilitate the ongoing development of the area's coal and salt industries. Additionally, the factory's establishment was seen as a way to decrease rates of deforestation by replacing wood-based products with plastic. On at least one occasion, the factory was accused of leaking thousands of tons of toxic waste into the Wuding River and failing to report the incident to authorities (Staff Writers, 2006). Thus, the factory's establishment linked state-led economic development processes into the area's social-ecological context, leading to polluted irrigation water that interacted with and shaped smallholder farmer crop selection decisions, which contributed to stabilizing maize as the dominant crop choice in our three study villages in Mizhi.

In summary, our results show that maize was continually planted because it fit well with how smallholder households structured and prioritized their livelihood strategies to manage various climatic and non-climatic risks, and because it mitigated the great-

est amount of risk and uncertainty emanating from the multiple stressors that impinged on their livelihoods (relative to other potential adaptation strategies). Specifically, when viewed in the context of the multiple stressors that impinge on agricultural production and livelihood decision-making, it becomes clear that stable prices, crop insurance, and other governmental support associated with maize production made it preferable to other higher-value crop choices. Planting maize also allowed smallholders to manage the markets risks that arose from high variability in prices, unfair buyer practices, and polluted irrigation water, while keeping their input costs low, ensuring they received at least some profit from maize production. Further, planting maize allowed smallholders to engage in off-farm wage work. Thus, as this example demonstrates, smallholders' decisions to plant maize did not occur independently of the multi-scalar pathways of change and response that shaped the risk management context in which they must make adaptive decisions. Further, this example shows that smallholders made adaptation decisions to not only address risks generated and experienced locally, but also manage multiple forms of uncertainty and capitalize on various livelihood opportunities in the context of large-scale social-ecological changes, including economic development initiatives often driven by governments, development agencies, or other non-local actors. Finally, this example demonstrates that planting maize was chosen and maintained by smallholder households as an adaptation strategy in part because it allowed smallholder households to retain flexibility through its low labor requirements that would allow them to manage future risks and uncertainties.

(c). Situating drip irrigation in the multi-scalar contexts of adaptation intervention

In this section, we present results from our interviews to show that failure to adopt drip irrigation as a state-led climate change adaptation intervention in Gansu can be attributed to the ways it created contradictions and tensions with the smallholder household livelihood practices designed to mitigate multiple forms of risk described in the previous section. In the Loess Plateau Region, and China more broadly, drip irrigation is frequently positioned as an adaptive solution to the predicted water stress that will result from climate change (Deng, Shan, Zhang, & Turner, 2006; Zou, Li, Gao, & Wan, 2012). In 2011, the Chinese government laid out a plan in their Central No. 1 Document to invest four trillion yuan (\$600 billion) in rural water resource development in the following decade, a plan that included improving agricultural irrigation efficiency through drip irrigation and other water efficient irrigation technologies (Yu, 2011). Likewise, China's National Plan for Coping with Climate Change advocates the use of drip irrigation as an adaptation to water scarcity (State Council Information Office of China, 2008).

In the Loess Plateau Region, particularly Gansu Province, significant financial and technical resources have been provided by the local, provincial, and regional governments, along with several large private agricultural companies, to promote the awareness and adoption of drip irrigation. Of our 13 study villages, two in Gansu had experience with drip irrigation, and the remaining 11 villages had not installed drip irrigation. However, local and provincial officials had expressed interest in promoting drip irrigation in these villages. As a result, many of our interviewees were familiar with drip irrigation even though they had not used it themselves.

Of the two villages that had experience with drip irrigation, the drip irrigation system was installed in one village by the local government in 2010, and in another by a private agricultural company in 2002. Prior to installation in both villages, interviewees used water from the Hei River to flood irrigate their crops. In both vil-

lages, the initial cost of installation was covered by either the local government or agricultural company, and farmers operated under contracts in which they were expected to hand their harvests over to a company at a price set at the beginning of the growing season. In addition, farmers were responsible for maintenance costs associated with the drip irrigation system, including new parts such as drip lines that need to be replaced every 2–3 years. Despite the financial and technical resources invested in establishing drip irrigation systems across our study site, the level of adoption and continuous use has been low among smallholder farmer households (Blanke, Rozelle, Lohmar, Wang, & Huang, 2007). In both our study villages where drip irrigation was installed, the system had been abandoned by all households.

(d). Smallholder adoption and abandonment of drip irrigation

Beyond the aforementioned contextual factors underlying the promotion of drip irrigation as a state-led adaptation intervention in China, our interviewees identified additional factors influencing their decision-making about drip irrigation adoption and continued use. Specifically, we draw from interview data collected in the two study villages in Gansu where drip irrigation systems were previously installed but then abandoned, to analyze how multi-scalar environmental, social, political, economic, and institutional processes and smallholder household risk management strategies interact with the adoption and maintenance of drip irrigation (Table 4). Burnham et al. (2015) contains a more detailed analysis of the human dimensions of drip irrigation adoption at the household level in northwest China. Below, we focus on two most important factors that contributed to the failure of drip irrigation systems over time.

(i). Time and labor availability

Interviewees in the two study villages reported similar reasons for choosing to abandon drip irrigation. The most commonly cited reason was the constraints it posed to their time and labor availability. Specifically, our interviewees pointed out that drip irrigation required them to change the amount of time they dedicated to agriculture and forced them to spend more time in the field than they were willing to. More specifically, traditional flood irrigation requires about six on-the-ground hours per day and five days of irrigation per growing season (for a total of 30 h), while drip irrigation requires about four on-the-ground hours per day and 10 days of irrigation per growing season (for a total of 40 h). Thus, drip irrigation requires not only more aggregate time in the field but more days dedicated to irrigation. Most of our interviewees disliked this time commitment because it meant they could not perform off-farm wage work on irrigation days.

Similar to the results reported about why smallholder households plant maize, our interviewees in these two villages had diversified their livelihoods through local wage work and labor migration to reduce climatic, market, and other forms of risk associated with agricultural production. In both villages, construction labor in a nearby city was the primary form of wage work, and this work was only available to men. This meant women frequently stayed in the villages to perform domestic duties, including agriculture, while men went off-farm and worked. In several interviewed households, this division of labor meant the increased labor burdens associated with drip irrigation fell on women, who did not like that drip irrigation added to their already heavy domestic responsibilities. Thus, the implementation of drip irrigation in the study villages directly contradicted the maize-cropping system that most of our interviewees had put in place to manage market risks and take advantage of its low labor input requirement in order to pursue wage-labor opportunities. In this way, drip irrigation existed in tension with household risk management and

livelihood priorities and competed with economic and non-economic demands on their time. It was these latter activities, particularly wage work, which determined how much time households were willing to commit to agricultural production.

(ii). Cooperation and the size and configuration of landholdings

The second commonly cited reason for the abandonment of drip irrigation concerned interhousehold cooperation. The use and maintenance of drip irrigation required households to cooperate with one another in ways that contradict the formal and informal social institutions that govern how agriculture landscapes were managed and labor performed in the two villages, practices driven in part by the existing land tenure system. In the early 1980s, the advent of the China's "Household Contract Responsibility System" decollectivized agricultural production in rural China, changing it from a communal farm system to one in which households received usufruct rights to farmland and became responsible for profits and losses. Prior to the introduction of the drip irrigation system in both of our study villages, our interviewees, on average, had access to 12–15 mu of land spread across three to four non-contiguous plots, within and outside of their villages. They were able to manage these plots of land largely independently of other households in their villages. In particular, when flood irrigation was practiced, water was delivered to each plot via a canal system, and each household could make irrigation decisions without having to coordinate with other households. In contrast, the way drip irrigation was set up led to a network of shared driplines in and around each village, with each dripline connecting, on average, five to six individually managed plots to a shared well. Water was delivered via the shared dripline at a time agreed upon by all the households whose plots of land shared the dripline. This means these households would have to coordinate with each other, as well as the village well manager to agree on a mutual time to irrigate before turning on the water.

This new need for cooperation induced by drip irrigation was problematic for two reasons. First, it was difficult for different households to agree on an irrigation schedule. This is partly because not all smallholder farmers are in the village and available to irrigate at the same time due to the fact that most smallholder households prioritized off-farm work over agriculture, as clearly expressed by our interviewees. In a few cases, this was also because different households planted crops with different water demands. In one village, several households whose fields connected through a dripline to the same well chose to grow different crops from each other, as they believed this would prevent the saturation of local markets with a single crop, keeping prices higher for everyone. Because of this, each plot required a different irrigation schedule, thus exacerbating the difficulty to agree on a common schedule, which led to conflicts. Second, there was lack of informal social institutions that facilitate cooperation. As one of our interviewee explained: "*In my village people cannot unite and cooperate with each other.*" Most of our interviewees had a strong preference for an irrigation schedule that allows them to manage their plots of land independently of other households. For example, an interviewee from Gaotai told us:

"If I had my own well, my own pump, my own water, and I could manage the water myself, I would choose to use drip irrigation and use it all the time."

Third, there were no clear rules in place to determine which household or village administrator had decision-making authority over setting up an irrigation schedule, particularly when a voluntary agreement could not be achieved. In both villages where drip irrigation were installed but later abandoned, disagreement and

the subsequent conflicts had led to some farmers disconnecting the driplines from the well in the middle of the night and using the water to flood irrigate their own plots.

Thus, not only did the use and maintenance of drip irrigation contradict the informal social institutions that valued independent farm management decision-making, there was also a lack of formal social institutions necessary to facilitative cooperative management of irrigation infrastructure, including a mechanism for conflict resolution. Further, the strong preference for independent farm management decision-making and lack of cooperative culture were shared among interviewees beyond the two study villages in Gansu with previous drip irrigation experience. Many interviewees reported that they foresaw conflicts between households if drip irrigation were to be introduced in their villages, as one woman who grew maize in Mizhi explained:

“If our family bought a drip irrigation system it would have to cross other families’ plots and this will probably cause conflicts. Sometimes families can work together, but normally there is too much conflict and not enough benefit.”

In summary, our results shows that even when a drip irrigation system was installed free of charge by non-local actors (government or private companies), its use tended to be temporary and the system was eventually abandoned. The failure of drip irrigation as an adaptation practice was the result of how its use reduced the amount of time smallholder households could dedicate to off-farm wage work, which was a highly prioritized livelihood strategy across our study villages, as well as how its use exposed them to agricultural market risk. Both reasons contradicted how planting maize allowed smallholder households to increase the amount of off-farm wage work they engaged and reduce agricultural market risk. The failure of drip irrigation was also the result of how its use forced households to cooperate when local social relations and norms shaped by multi-scalar pathways of change and response had engendered non-cooperative agricultural management systems. This example demonstrates how particular adaptation strategies promoted as part of one state-led intervention interact with other past and ongoing adaptation interventions and the associated changes in local social institutions that underlie smallholder livelihood and agricultural management practices, leading to their failure or success. Moreover, this example demonstrates how household-level adaptive practices interact with state-led adaptation interventions in the context of various cross-scalar policy and social transitions, and together change household livelihood opportunities and potentially limit or expand possibilities for future adaptation.

6. Conclusion

The development of effective adaptation governance requires in-depth, situated understanding of how adaptation is embedded in particular environmental, social, political, economic, and institutional contexts. Using a multi-scalar pathways lens, this paper investigated two adaptation strategies (planting maize and adopting drip irrigation) to highlight three primary findings. *First*, smallholder household decision to adopt an adaptation strategy is shaped by historical and ongoing multi-scalar, social-ecological change, and tensions arise when a new adaptation intervention contradicts local social institutions and when it creates tradeoffs with other risk management strategies that smallholder households employ, leading it to fail. *Second*, an adaptation strategy is likely to be maintained and persist over time if it allows smallholder households to not only synergistically manage multiple attendant risks that are experienced locally but also be able to mitigate potential risks in an uncertain future. *Third*, legacies of past

adaptation undertaken by smallholder households and adaptation interventions introduced by non-local actors interact to shape smallholder exposure to current and future stressors and the adaptation pathways that enable smallholders to maintain choices in terms of managing future risks and uncertainties.

Specifically, our multi-scalar pathways approach enabled us to view smallholder adaptation as part of ongoing pathways of change and response that allow smallholders to navigate dynamic environmental and institutional landscapes in ways that mitigate multiple forms of risk and uncertainty across the greatest number of stressors in the present, while maintaining the flexibility for developing livelihood strategies to absorb future risks. For example, planting maize, coupled with other state-led agricultural advancements (e.g., drought-tolerant seeds and plastic mulching), allowed smallholders in our study to not only reduce their vulnerability to changes in weather patterns and climate, but also mitigate market risk associated with unstable prices, continue crop production with polluted irrigation water linked to state-led economic development initiatives, and free up time for off-farm wage work, further reducing dependence on agricultural production. In brief, planting maize persisted as an adaptation strategy because it allowed for the most amount of current and future risks to be managed. Drip irrigation, on the other hand, failed because it forced smallholder households to spend more time on irrigation and farming than they were willing to, thus decreasing household labor mobility and inhibiting their ability to perform off-farm wage work as a strategy to reduce current and future risks associated with dependence on agriculture production. As such, adopting drip irrigation exposed smallholder households to the very same risks that planting maize and allowed them to mitigate, and further contradicted the flexibility in preserving future adaptation alternatives that planting maize allowed for. In this way, planting maize as an adaptation strategy sets up a pathway through which the possibilities for successfully implementing drip irrigation are foreclosed. Further, our results demonstrate that different adaptation strategies often entail different tradeoffs between present and future risk management domains, and such tradeoffs are always explicitly or implicitly considered by smallholder households when making adaptation decisions. Together, our results suggest that adaptation decisions may not be shaped by a changing climate (or other environmental change) as much as they are shaped by the attempts of smallholder households to manage risks across multiple social-ecological sectors over time.

Additionally, our results demonstrate that particular forms of adaptation are reproduced or abandoned in part because of synergies or tensions arose from local social institutions. In other words, an adaptation strategy is adopted and reproduced because it not only engenders favorable material outcomes or risk management potential, but also mobilizes and maintains the social institutions that govern how smallholder households manage their agricultural production and livelihoods. For example, it became clear that the failure of drip irrigation as an adaptation to water scarcity is in part a result of a myopic focus on addressing biophysical change at the expense of understanding how broader social, political, and economic dynamics shape local social institutions, which in turn shape adaptation decisions and outcomes. In particular, the advent of China’s “Household Contrast Responsibility System” led to various agricultural and rural reforms that conditioned the popularity of smallholder labor migration and off-farm wage work, together creating a set of informal institutions that privileged non-cooperative agricultural management within villages. Drip irrigation contradicted such social institutions by demanding households to collaboratively establish and implement an irrigation schedule, which led to conflicts between households and system abandonment. From the pathways perspective, drip irrigation offers a single path to address a single stressor (i.e., change in cli-

matic conditions) without taking into account the existing local social institutions; while in reality smallholder households operate within social relations and norms that are shaped by legacies of past and ongoing adaptation pathways, as defined by Barnett et al. (2014).

From a practice perspective, our results provided two specific insights that can be helpful for the design and implementation of adaptation and development interventions to assist smallholder households in addressing climatic and other social–ecological changes. The first insight points to a critical need for adaptation and development interventions to create synergies with ongoing smallholder adaptation and livelihood practices (e.g., the labor flexibility conferred by planting maize) and enable them to continue to manage not just climate change but the multiple stressors, uncertainties, and opportunities they face in culturally appropriate ways. Otherwise, such interventions run the risk of causing unintended consequences, exposing smallholders to new forms of risk, or reducing their ability to experiment and adapt on their own, in both the present and future. The second insight points to the importance of understanding not only why particular adaptive strategies are adopted by smallholders but also why some become persistent while others are discontinued. To do so, future research should not only document successful adaptation cases but focus on adaptation options that either failed to take hold or were once adopted but eventually abandoned. Such focus will generate insights into the range of risks, barriers, opportunities, and incentives smallholders face and respond to, decreasing the likelihood that adaptation interventions contradict ongoing adaptation pathways. More importantly, adaptation research and policy design need to consistently and continuously engage smallholders through meaningful participatory processes that enable fair and effective adaptation options that smallholders can take ownership of (Wise et al., 2014). As such, a pathway-based approach to adaptation is important for supporting iterative decision-making processes that can address various forms of uncertainty and contested multi-stakeholder interests in complex social–ecological systems, while still maintaining options for future adaptation (Butler et al., 2014, 2016).

Finally, our study is not without limitations. Because we were limited in our ability to obtain data to differentiate our interviewees in terms of their social groups, our study homogenizes households across the Loess Plateau. However, recent research has demonstrated that a pathway-based approach can be valuable for highlighting how different adaptation pathways arise for different social groups, thus providing insight into differential vulnerability and the processes that facilitate and constrain adaptation across these social groups (Câmpeanu & Fazey, 2014; Fazey et al., 2016). In addition, we recognize that our multi-scalar approach focuses on community, regional, and national dynamics at the expense of intrahousehold relations, thus treating households as largely homogenous units (Bhattarai, Beilin, & Ford, 2015). This is due to the way that our study was designed, which limited our ability to explore intrahousehold relations as socially dynamic processes that shape adaptation pathways. Future research on the Loess Plateau and elsewhere could benefit from examining how intersections between social group, gender, and other factors affect adaptation pathways and how adaptation interventions create differential synergies, contradictions, and tensions across different segments of the populations.

Acknowledgments

This research was partially funded by China's Northwest Agricultural and Forestry University through the 111 project of the Chinese Ministry of Education (No. B12007). This paper was motivated by a shared interest among a group of researchers who partici-

pated in the 4th international conference of the Initiative on Climate Adaptation Research and Understanding through the Social Sciences (ICARUS) in 2015. We thank the support from Arun Agrawal and Maria Lemos for the opportunity to organize a writeshop that facilitated the completion of this paper. We thank all the writeshop participants for their suggestions and encouragement. In particular, we thank Paige Fischer and Laura Vang Rasmussen for their thorough and thoughtful comments on drafts of this paper. We also thank Cristy Watkins for her support and assistance. Finally, we thank the anonymous reviewers who provided helpful comments.

References

- Adger, W. N. (2003). Social aspects of adaptive capacity. In J. B. Smith, R. J. T. Klein, & S. Huq (Eds.), *Climate change, adaptive capacity and development* (pp. 29–49). London, U.K.: Imperial College Press.
- Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, 16, 268–281.
- Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change*, 15(2), 77–86.
- Adger, N. W., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D. R., et al. (2009). Are there social limits to adaptation to climate change? *Climatic Change*, 93, 335–354.
- Adger, W. N., & Vincent, K. (2005). Uncertainty in adaptive capacity. *Comptes Rendus Geoscience*, 337(4), 399–410.
- Agrawal, A. (2010). Local institutions and adaptation to climate change. In R. Mearns & A. Norton (Eds.), *The social dimensions of climate change: Equity and vulnerability in a warming world* (pp. 173–197). Washington, D.C.: World Bank Publications.
- Agrawal, A., & Perrin, N. (2009). Climate adaptation, local institutions and rural livelihoods. In W. N. Adger, I. Lorenzoni, & K. L. O'Brien (Eds.), *Adapting to climate change: thresholds, values, governance* (pp. 350–367). Cambridge, U.K.: Cambridge University Press.
- Barnett, J., Graham, S., Mortreux, C., Fincher, R., Waters, E., & Hurlimann, A. (2014). A local coastal adaptation pathway. *Nature Climate Change*, 4, 1103–1108.
- Bawakyillenuo, S., Yaro, J. A., & Teye, J. (2016). Exploring the autonomous adaptation strategies to climate change and climate variability in selected villages in the rural northern savannah zone of Ghana. *Local Environment*, 21(3), 361–382.
- Bhattarai, B., Beilin, R., & Ford, R. (2015). Gender, agrobiodiversity, and climate change: A study of adaptation practices in the Nepal Himalayas. *World Development*, 70, 122–132.
- Birkenholtz, T. (2012). Network political ecology: method and theory in climate change vulnerability and adaptation research. *Progress in Human Geography*, 36(3), 295–315.
- Blanke, A., Rozelle, S., Lohmar, B., Wang, J., & Huang, J. (2007). Water saving technology and saving water in China. *Agricultural Water Management*, 87(2), 139–150.
- Burnham, M., & Ma, Z. (2017). Climate change adaptation: Factors influencing Chinese smallholder farmers' perceived self-efficacy and adaptation intent. *Regional Environmental Change*, 17(1), 171–186.
- Burnham, M., & Ma, Z. (2016). Linking smallholder farmer climate change adaptation decisions to development. *Climate and Development*, 8(4), 289–311.
- Burnham, M., Ma, Z., & Zhu, D. (2015). The human dimensions of water saving irrigation: lessons learned from Chinese smallholder farmers. *Agriculture and Human Values*, 32(2), 347–360.
- Butler, J. R. A., Suadnya, W., Puspadi, K., Sutaryono, Y., Wise, R. M., Skewes, T. D., ... Ash, A. (2014). Framing the application of adaptation pathways for rural livelihoods and global change in eastern Indonesian islands. *Global Environmental Change*, 28, 368–382.
- Butler, J. R. A., Suadnya, W., Yanuartati, Y., Meharg, S., Wise, R. M., Sutaryono, Y., & Duggan, K. (2016). Priming adaptation pathways through adaptive co-management: Design and evaluation for developing countries. *Climate Risk Management*, 12, 1–16.
- Campbell, J. L., Quincy, C., Osserman, J., & Pedersen, O. K. (2013). Coding in-depth semistructured interviews. *Sociological Methods & Research*, 42(3), 294–320.
- Câmpeanu, C. N., & Fazey, I. (2014). Adaptation and pathways of change and response: A case study from Eastern Europe. *Global Environmental Change*, 28, 351–367.
- Carr, E. R. (2008). Between structure and agency: Livelihoods and adaptation in Ghana's central region. *Global Environmental Change*, 18(4), 689–699.
- Crane, T. A., Roncoli, C., & Hoogenboom, G. (2011). Adaptation to climate change and climate variability: The importance of understanding agriculture as performance. *NJAS-Wageningen Journal of Life Sciences*, 57(3), 179–185.
- Curry, G. N., Koczberski, G., Lummani, J., Nailina, R., Peter, E., McNally, G., & Kuaimba, G. (2015). A bridge too far? The influence of socio-cultural values on the adaptation responses of smallholders to a devastating pest outbreak in cocoa. *Global Environmental Change*, 35, 1–11.
- Day, A. F. (2013). A century of rural self-governance reforms: Reimagining rural Chinese society in the post-taxation era. *Journal of Peasant Studies*, 40(6), 929–954.

- Deng, X., Shan, L., Zhang, H., & Turner, N. C. (2006). Improving agricultural water use efficiency in arid and semiarid areas of China. *Agricultural Water Management*, 80(1–3), 23–40.
- Ding, Y., & Chan, J. C. L. (2005). The East Asian summer monsoon: An overview. *Meteorology and Atmospheric Physics*, 89(1–4), 117–142.
- Eakin, H. (2000). Smallholder maize production and climatic risk: A case study from Mexico. *Climatic Change*, 45(1), 19–36.
- Eakin, H. (2005). Institutional change, climate risk, and rural vulnerability: Cases from Central Mexico. *World Development*, 33(11), 1923–1938.
- Eakin, H., & Luers, A. L. (2006). Assessing the vulnerability of social-environmental systems. *Annual Review of Environment and Resources*, 31, 365–394.
- Eakin, H., Winkels, A., & Sendzimir, J. (2009). Nested vulnerability: exploring cross-scale linkages and vulnerability teleconnections in Mexican and Vietnamese coffee systems. *Environmental Science & Policy*, 12(4), 398–412.
- Eriksen, S., Aldunce, P., Bahinipati, C. S., Martins, R. D., Molefe, J. I., Mhemachena, C., et al. (2011). When not every response to climate change is a good one: identifying principles for sustainable adaptation. *Climate and Development*, 3, 7–20.
- Fan, C. C. (2003). Rural-urban migration and gender division of labor in transitional China. *International Journal of Urban and Regional Research*, 27(1), 24–47.
- Fazey, I., Wise, R. M., Lyon, C., Câmpăanu, C., Moug, P., & Davies, T. E. (2016). Past and future adaptation pathways. *Climate and Development*, 8(1), 26–44.
- Feola, G., Lerner, A. M., Jain, M., Montefrio, M. J. F., & Nicholas, K. A. (2015). Researching farmer behaviour in climate change adaptation and sustainable agriculture: Lessons learned from five case studies. *Journal of Rural Studies*, 39, 74–84.
- Field, C. B. (2012). *Managing the risks of extreme events and disasters to advance climate change adaptation: special report of the intergovernmental panel on climate change*. Cambridge, U.K.: Cambridge University Press.
- Food and Agriculture Organization (FAO) (2011). *Aquastat: China* Retrieved from http://www.fao.org/nr/water/aquastat/countries_regions/CHN/CP_CHN.pdf.
- Forsyth, T., & Evans, N. (2013). What is autonomous adaption? Resource scarcity and smallholder agency in Thailand. *World Development*, 43, 56–66.
- Frank, E., Eakin, H., & López-Carr, D. (2011). Social identity, perception and motivation in adaptation to climate risk in the coffee sector of Chiapas, Mexico. *Global Environmental Change*, 21(1), 66–76.
- Fraser, E. D. G., Termansen, M., Sun, N., Guan, D., Simelton, E., Dodds, P., et al. (2008). Quantifying socioeconomic characteristics of drought-sensitive regions: Evidence from Chinese provincial agricultural data. *Comptes Rendus Geoscience*, 340(9–10), 679–688.
- Grothmann, T., & Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. *Global Environmental Change*, 15(3), 199–213.
- Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change*, 23(2), 485–498.
- Hageback, J., Sundberg, J., Ostwald, M., Chen, D., Yun, X., & Knutsson, P. (2005). Climate variability and land-use change in Danangou watershed, China—Examples of small-scale farmers' adaptation. *Climatic Change*, 72(1–2), 189–212.
- Harmer, N., & Rahman, S. (2014). Climate change response at the farm level: A review of farmers' awareness and adaptation strategies in developing countries. *Geography Compass*, 8(11), 808–822.
- Huang, G., Chen, W., & Li, F. (2011). Rainfed farming systems in the Loess Plateau of China. In P. Tow, I. Cooper, I. Partridge, & C. Birch (Eds.), *Rainfed farming systems* (pp. 643–669). Springer.
- Huang, J., Pray, C., & Rozelle, S. (2002). Enhancing the crops to feed the poor. *Nature*, 418(6898), 678–684.
- Huang, J., & Rozelle, S. (2008). China: Maize economy, incentives and policies. In A. Gulati & J. Dixon (Eds.), *Maize policies in Asia: Changing markets and incentives* (pp. 93–186). New Delhi, India: Academic Foundation.
- Huitema, D., Adger, W. N., Berkhout, F., Massey, E., Mazmanian, D., Munaretto, S., ... Termeer, C. C. J. A. M. (2016). The governance of adaptation: Choices, reasons, and effects. Introduction to the Special Feature. *Ecology and Society*, 21(3), 37.
- Intergovernmental Panel on Climate Change (IPCC) (2007). *Climate Change 2007: Impacts, adaptation and vulnerability*. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge, U.K.: Cambridge University Press.
- Jones, L., & Boyd, E. (2011). Exploring social barriers to adaptation: Insights from western Nepal. *Global Environmental Change*, 21(4), 1262–1274.
- Jones, R. N., & Preston, B. L. (2011). Adaptation and risk management. *WIREs Climate Change*, 2(2), 296–308.
- Leach, M., Scoones, I., & Stirling, A. (2010). *Dynamic sustainabilities: Technology, environment and social justice*. London, U.K.: Earthscan Publications.
- Leichenko, R., & O'Brien, K. (2008). *Environmental change and globalization: double exposures*. Oxford, U.K.: Oxford University Press.
- Leichenko, R., & Silva, J. A. (2014). Climate change and poverty: Vulnerability, impacts, and alleviation strategies. *WIREs Climate Change*, 5(4), 539–556.
- Lemos, M. C., Boyd, E., Tompkins, E. L., Osbahr, H., & Liverman, D. (2007). Developing adaptation and adapting development. *Ecology and Society*, 12(2), 26.
- Li, Z., Zheng, F. L., & Liu, W. Z. (2012). Spatiotemporal characteristics of reference evapotranspiration during 1961–2009 and its projected changes during 2011–2099 on the Loess Plateau of China. *Agricultural and Forest Meteorology*, 154–155, 147–155.
- Li, Z., Zheng, F. L., Liu, W. Z., & Flanagan, D. C. (2010). Spatial distribution and temporal trends of extreme temperature and precipitation events on the Loess Plateau of China during 1961–2007. *Quaternary International*, 226(1), 92–100.
- Manuel-Navarrete, D., & Pelling, M. (2015). Subjectivity and the politics of transformation in response to development and environmental change. *Global Environmental Change*, 35, 558–569.
- McDowell, J. Z., & Hess, J. J. (2012). Accessing adaptation: Multiple stressors on livelihoods in the Bolivian highlands under a changing climate. *Global Environmental Change*, 22(2), 342–352.
- Meng, E. C. H., Hu, R., Shi, X., & Zhang, S. (2006). *Maize in China: Production systems, constraints, and research priorities*. El Batán, Mexico: International Maize and Wheat Improvement Center (CIMMYT).
- Mercur, K. L., Perales, H. R., & Wainwright, J. D. (2012). Climate change and the transgenic adaptation strategy: Smallholder livelihoods, climate justice, and maize landraces in Mexico. *Global Environmental Change*, 22(2), 495–504.
- Mertz, O., Mbow, C., Nielsen, J. Ø., Maiga, A., Diallo, D., Reenberg, A., et al. (2010). Climate factors play a limited role for past adaptation strategies in West Africa. *Ecology and Society*, 15(4), 25.
- Mertz, O., Mbow, C., Reenberg, A., & Diouf, A. (2009). Farmers' perceptions of climate change and agricultural adaptation strategies in rural Sahel. *Environmental Management*, 43(5), 804–816.
- Milman, A., & Warner, B. P. (2016). The interfaces of public and private adaptation: Lessons from flooding in the Deerfield River Watershed. *Global Environmental Change*, 36, 46–55.
- Naess, L. O. (2013). The role of local knowledge in adaptation to climate change. *WIREs Climate Change*, 4(2), 99–106.
- Nelson, M. C., Ingram, S. E., Dugmore, A. J., Streeter, R., Peeples, M. A., McGovern, T. H., et al. (2016). Climate challenges, vulnerabilities, and food security. *Proceedings of the National Academy of Sciences*, 113(2), 298–303.
- Neuman, W. L. (2011). *Social research methods: qualitative and quantitative approaches* (7th ed.). Boston, MA: Pearson.
- Nielsen, J. Ø., & Reenberg, A. (2010). Temporality and the problem with singling out climate as a current driver of change in a small West African village. *Journal of Arid Environments*, 74(4), 464–474.
- Orlove, B. (2009). The past, the present and some possible futures of adaptation. In W. N. Adger, I. Lorenzoni, & K. O'Brien (Eds.), *Adapting to climate change: Thresholds, values, governance* (pp. 131–163). Cambridge, U.K.: Cambridge University Press.
- Orr, A., & Mwale, B. (2001). Adapting to adjustment: Smallholder livelihood strategies in southern Malawi. *World Development*, 29(8), 1325–1343.
- Osborne, H., Dorward, P., Stern, R., & Cooper, S. (2011). Supporting agricultural innovation in Uganda to respond to climate risk: Linking climate change and variability with farmer perceptions. *Experimental Agriculture*, 47(2), 293–316.
- Osborne, H., Twyman, C., Adger, W. N., & Thomas, D. S. (2008). Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. *Geoforum*, 39(6), 1951–1964.
- Pelling, M., & High, C. (2005). Understanding adaptation: What can social capital offer assessments of adaptive capacity? *Global Environmental Change*, 15, 308–319.
- Piao, S., Ciais, P., Huang, Y., Shen, Z., Peng, S., Li, J., et al. (2010). The impacts of climate change on water resources and agriculture in China. *Nature*, 467, 43–51.
- Reed, M. S., Podesta, G., Fazey, I., Geeson, N., Hessel, R., Hubacek, K., et al. (2013). Combining analytical frameworks to assess livelihood vulnerability to climate change and analyse adaptation options. *Ecological Economics*, 94, 66–77.
- Roco, L., Engler, A., Bravo-Ureta, B., & Jara-Rojas, R. (2014). Farm level adaptation decisions to face climatic change and variability: Evidence from Central Chile. *Environmental Science & Policy*, 44, 86–96.
- Rodima-Taylor, D., Olwig, M. F., & Chhetri, N. (2012). Adaptation as innovation, innovation as adaptation: An institutional approach to climate change. *Applied Geography*, 33, 107–111.
- Scoones, I. (2009). Livelihoods perspectives and rural development. *The Journal of Peasant Studies*, 36(1), 171–196.
- Singh, C., Dorward, P., & Osbahr, H. (2016). Developing a holistic approach to the analysis of farmer decision-making: Implications for adaptation policy and practice in developing countries. *Land Use Policy*, 59, 329–343.
- Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change*, 16, 282–292.
- Spence, A., Poortinga, W., & Pidgeon, N. (2012). The psychological distance of climate change. *Risk Analysis*, 32(6), 957–972.
- Staff Writers (2006). *Company accused of releasing chemicals into Chinese River*. Terra Daily Retrieved from http://www.terradaily.com/reports/Company_Accused_Of_Releasing_Chemicals_Into_Chinese_River.html.
- State Council Information Office of China (2008). *China's policies for addressing climate change*. Beijing, China: State Council Information Office of China.
- Taylor, M. (2015). *The political ecology of climate change adaptation: Livelihoods, agrarian change, and the conflicts of development*. London, U.K.: Routledge.
- Thomalla, F., Downing, T., Spanger-Sieghfried, E., Han, G., & Rockström, J. (2006). Reducing hazard vulnerability: Towards a common approach between disaster risk reduction and climate adaptation. *Disasters*, 30(1), 39–48.
- Thomas, D. S., Twyman, C., Osbahr, H., & Hewitson, B. (2007). Adaptation to climate change and variability: Farmer responses to intra-seasonal precipitation trends in South Africa. *Climatic Change*, 83(3), 301–322.
- Thorn, J., Thornton, T. F., & Helfgott, A. (2015). Autonomous adaptation to global environmental change in peri-urban settlements: Evidence of a growing culture

- of innovation and revitalisation in Mathare Valley Slums, Nairobi. *Global Environmental Change*, 31, 121–131.
- Tilt, B. (2008). Smallholders and the 'Household Responsibility System': Adapting to institutional change in Chinese agriculture. *Human Ecology*, 36(2), 189–199.
- Tucker, C. M., Eakin, H., & Castellanos, E. J. (2010). Perceptions of risk and adaptation: Coffee producers, market shocks, and extreme weather in Central America and Mexico. *Global Environmental Change*, 20(1), 23–32.
- Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., et al. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, 100, 8074–8079.
- Veeck, G., & Shui, W. (2011). China's quiet agricultural revolution: Policy and programs of the new millennium. *Eurasian Geography and Economics*, 52(2), 242–263.
- Wang, J., Brown, D. G., & Agrawal, A. (2013). Climate adaptation, local institutions, and rural livelihoods: A comparative study of herder communities in Mongolia and Inner Mongolia, China. *Global Environmental Change*, 23(6), 1673–1683.
- Wise, R. M., Fazey, I., Smith, M. S., Park, S. E., Eakin, H. C., Van Garderen, E. A., & Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change*, 28, 325–336.
- Wolf, J., Allice, I., & Bell, T. (2013). Values, climate change, and implications for adaptation: evidence from two communities in Labrador, Canada. *Global Environmental Change*, 23(2), 548–562.
- Wu, W., Verburg, P. H., & Tang, H. (2013). Climate change and the food production system: impacts and adaptation in China. *Regional Environmental Change*, 14(1), 1–5.
- Yang, X., Lin, E., Ma, S., Ju, H., Guo, L., Xiong, W., et al. (2007). Adaptation of agriculture to warming in Northeast China. *Climatic Change*, 84(1), 45–58.
- Ye, J., Wang, C., Wu, H., He, C., & Liu, J. (2013). Internal migration and left-behind populations in China. *The Journal of Peasant Studies*, 40(6), 1119–1146.
- Yeh, E. T. (2005). Green governmentality and pastoralism in western China: 'Converting pastures to grasslands'. *Nomadic Peoples*, 9(1–2), 9–30.
- Yeh, E. T., Nyima, Y., Hopping, K. A., & Klein, J. A. (2014). Tibetan pastoralists' vulnerability to climate change: A political ecology analysis of snowstorm coping capacity. *Human Ecology*, 42(1), 61–74.
- Yu, C. (2011). China's water crisis needs more than words. *Nature*, 470, 307.
- Zhang, B., Wu, P., Zhao, X., & Gao, X. (2013). Spatiotemporal analysis of climate variability (1971–2010) in spring and summer on the Loess Plateau, China. *Hydrological Processes*, 28(4), 1689–1702.
- Zhu, X., Li, Y., Li, M., Pan, Y., & Shi, P. (2013). Agricultural irrigation in China. *Journal of Soil and Water Conservation*, 68(6), 147A–154A.
- Zou, X., Li, Y., Gao, Q., & Wan, Y. (2012). How water saving irrigation contributes to climate change resilience—a case study of practices in China. *Mitigation and adaptation strategies for global change*, 17(2), 111–132.